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THE CHALLENGE OF G-376

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ABSTRACT

This paper will review the entire G-376 project from history, experiment concept, construction, testing, through post flight data reduction. For each of these topics, one or two specific experiments will be used as an example to develop that topic. Refer to table one for a summary of the 14 experiments.

INTRODUCTION

When G-376 flies it will be no small accomplishment but the result of years of hard work by groups of students, teachers, and sponsors. G-376 is a project begun in 1982 and contains 14 experiments from eleven Maryland public high schools. It is sponsored by Orbital Systems, Ltd., in Lanham, Maryland. The project contains four biological experiments, three microbiological experiments, two materials processing experiments and five physical science experiments. The main power supply is eight lantern batteries equivalent to 128 D cells in 12V and 5V busses. Twelve experiments require power from the main power supply. There are three 35mm cameras. Ten experiments developed their own timing control capability to perform multiple functions at specified intervals. Eight experiments activate their experiment by applying a force to combine two objects separated by a barrier - though each solved the problem differently. This project is a testament to the creativity and ingenuity of today's high school student when a challenge is freely accepted.

The challenge was to design, develop, build and deliver a microgravity experiment. It must be safe, self-contained, and require only power from the can. Each group of students organized itself with a teacher serving as an advisor and decided on a concept for their experiment. It was then up to the group to determine the complexity of their experiment and produce a workable design. They could chose to seek outside help or design and build totally in-house. After a workable design was completed, the groups built and tested and redesigned until it really worked. Even at the time of this paper, the work and testing continues.

HISTORY

Each experiment has a unique and interesting history. The Planaria project's original proposal to examine the effect of microgravity on the regeneration of worms was made by two juniors in the spring of 1982. The working group was formed and began its research in the fall of 1982; fortunately most of the members were freshman and remained active members of the group throughout their four years of high school. The working philosophy of the original Planaria group was to complete the project with a minimal amount of outside help. This resulted in slow progress and much trial-and-error learning but much valuable experience in problem solving.

Because of its ability to regenerate quickly, its hardiness, and the extent of previous study of its regeneration, the Planarian was chosen as the experimental animal. The biggest challenge arose in designing a container in which the Planaria could live. This container had to include an automatic mechanism that would section and preserve the Planaria while in orbit. The early attempts at construction were frustrated by lack of equipment. Experimentation with planarian behavior under varying conditions and maintaining the Planarian cultures over the years provided another struggle. An example of this was the discovery that Planaria pull themselves apart. This realization explained the seemingly random multiplication of planaria in their culture dishes. Another problem was the fierce technical debate that ensued in choosing a method of preserving the Planaria. These challenges taught problem solving and technical planning. The original students learned these lessons and set the foundations for the present group.

ORGANIZATION

None of the experiments could be completed without good organization. One of the more highly organized groups is the Bacteriophage experiment. In order to produce the Bacteriophage experiment, teachers and students have been recruited every year. More than twenty teachers and one hundred four students have been involved in this one project since 1982. Recruitment of the students occurs yearly in grades nine through twelve. Slide presentations, displays, and showcases advertise the project. Students who are interested in the project are asked to read press releases and information about the project. This yearly recruitment of students helps ensure the continuity of the project. The older members inform the new members of the methods and procedures required to produce the project.

The project is divided into specific areas. These include the following: manufacturing, public relations, displays, electronics, report writing, drafting, printing, art, and photography. Students may select the area in which they are most interested. Students who are not interested in the scientific aspects of the project may become involved in the club's fund-raising activities which support the financial needs of the project. The funds raised purchase raw materials for manufacturing, film, display materials, and other essentials. Members of the club are identified by a logo button developed by the art department. The club distributes these buttons to members who have actively participated in the project's success.

Teachers from all departments in the school are recruited by the coordinators and students. Students must explain the project to the teachers and enlist their help with specific problems.

Successful coordination of the Bacteriophage project requires approximately two hours of work every day by the sponsors and students. Students working on different aspects of the project such as public relations, photography, etc., assemble as an entire group to present general updates of information. The separate divisions also meet with teachers who are expert in their specific fields. This collaboration insures the continued progress and continuity of all aspects of the project.

Presentations of the project have been given to the Parent Teacher Student Association, Prince George's County Board of Education, civic groups, NASA as well as other schools. Students are also given special recognition at the school's annual awards program.

Future plans for the Bacteriophage group are formulated each spring for the coming school year. Some of these include manufacturing of mockups for testing and displays, continued recruitment of students, computer training, analysis of space related scientific articles, and scheduling of future presentations.

EXPERIMENT CONCEPT

The development of the experiment concept into a workable design is the first major step of the process. The Nematode project is unique in that it has not been done in any previous flights. The project proposes to examine the rate of growth of the Nematode, a small worm called Caenerhabditis elegans. The experiment takes Nematodes in a dormant stage, allows them to grow and then fixes them at different life stages. The returned samples will be taken to a laboratory and the growth rates will be compared to a ground control group. The factors to consider include male to female ratio, birth defects, and effects of cosmic and electromagnetic radiation in the space environment. A critical factor in this experiment is maintaining the proper environment for the Nematodes from the time they are sealed at the launch site until they are returned to the school after the flight.

The design of the Nematode experiment has to accomplish all of these objectives to return useful data. The essential design of the experiment includes an Aluminum box container, a block of solid plastic separated into two halves from which the chambers are drilled, an electronics box, and a phase change heat cell to maintain temperature requirements. The chamber block, constructed from two slabs of Lexan plastic, contains two redundant sets of ten chambers. Each of the twenty chambers consists of the growth segment, where approximately 100 Nematodes are stored, a food housing and a fixative housing which are separated from the growth segment by small glass dimple actuators which shatter upon command from the controller circuit. All of the food actuators fire sequentially when the experiment is activated and the fixative actuators fire at timed intervals.

Over the past four years, there have been several changes in the design. Some of the problems encountered in earlier models include: material strength problems with the plastic used, displacement of air in the chambers, leakage from vibrations and the controls for the safe initiation of the dimple actuators. The present design has two blocks of Lexan glued together to prevent leakage and is strong enough to meet the structural requirements. The control circuit insures the dimple actuators to be safe and efficiently uses power by sequencing the firing of the food releasing actuators instead of firing them simultaneously. The phase change heat cell, containing calcium chloride hexahydrate and bisol II will keep the Nematodes within the temperature limits.

Preparing the Nematodes for flight will take several months immediately before launch. The Nematodes all have to be in the same life stage prior to injection into the experiment and they also must be capable of being dormant for several weeks.

The Protein Production of bacteria experiment has the same two stage operation as the Nematode experiment. The bacteria begins in a freeze dried state in the center section of two ALCAR plastic bags. To one side, separated by a barrier, is the food. On the other side is the fixative. This experiment uses two stepper motors to release the barriers when the controller circuit actuates the mechanism. The Protein Production experiment requires strict temperature limits (37 +10 degrees C) during the mission so it contains a thermostatically controlled heater.

CONSTRUCTION

Hardware for G-376 has been constructed in every imaginable place from basements to school classrooms to government institutions to private shops and laboratories. The biological experiments developed techniques to incorporate sterile material into their projects before launch. Experiments constructed in-house showed the student's methods of hardware construction.

The Radish Seed experiment was constructed by students in a machine shop. The experiment expects to photograph the germination of seeds in microgravity. When the experiment is activated, the seeds have to be injected into the growth chamber. To do this the students devised a solenoid driven plunger assembly consisting of ten rods which have seeds at the end. The force of the solenoid drives the seeds through a thin plastic shield into the growth medium while the solenoid pulls its own power plug. Hours of machining was required to create a leakproof container and a low friction sliding mechanism that withstands the force of the solenoid.

The Solid Foam experiment combines polymeric methylene diphenyl isocyanate with freon in a polyol solution to produce a solid structure. The entire experiment was constructed in-house. The two liquids, contained in syringes, are released by a motor driven push-plate and injected into a chamber where they combine to form the foam. But the liquids have to be mixed thoroughly or the foam will not be uniform. After several failures, a block of plastic was drilled out to allow the liquids to flow together for several centimeters before reaching the chamber. The difficult part was insuring that the mixing chamber would not impede the flow or leak - either of which would effectively ruin the experiment.

TESTING

Designing an experiment and buiding it does not complete the process. It has to be tested to insure that it will work as planned. For most of the experiments there was more time spent testing and redesigning than designing and building. The Polyethylene melt experiment is a good example of this idea. This experiment wants to examine the structure of Polyethylene plastic melted in space. Polyethylene melts at 163 degrees C. First an efficient heating method had to be designed to minimized power. The final design is an Aluminum container with two cylindrical heating coils to melt the various shapes of Polyethylene packed inside the container. The various Polyethylene shapes maximize the surface area for faster melting. A problem that only testing could fix was the amount of power required to melt the plastic and a method of turning off that power after the experiment was finished or a failure occurred. A 12V, 16 D cell power supply was found to melt the Polyethylene in less than two hours. The redundant power cutoff system uses three independent methods: a thermostat cutoff switch, a timer circuit and a second thermal switch made of Polyethylene that opens when the plastic melts. Overheating of the can was overcome in the laboratory by using enough insulation.

The Liesegang Bands experiment will photograph the reaction of potassium chromate and copper acetate in agar. All testing was done in-house. The chemical testing was carried out in two phases. First a suitable gel had to be found. Gels such as sodium silicate, unflavored gelatin, and agar were observed as they were subjected to freezing and temperatures around 200 degrees F. They were alternately subjected to the temperature extremes for periods varying from several hours to several days. The agar appeared to show the least responses to such temperature variations.

The reacting chemicals were selected after the best gel was found. Several chemical combinations, such as potassium chromate and copper acetate, potassium chromate and silver nitrate, lead acetate and potassium iodide, cobalt nitrate and ammonium hydroxide, were tested and their crystal formation evaluated and photographed. The combination of potassium chromate and copper acetate was selected because of the formation of brown crystals that contrasted well with the color of the agar containing the chromate. This combination photographed well.

Potassium chromate and copper acetate were allowed to react under varying temperature conditions and maintained in the laboratory for as long as two months. The crystals held up well under temperature variations, and for as long as two months.

Mechanical testing of the injecting mechanism involved a variety of procedures including solenoids, plastic and glass tubes, and plastic and glass syringes. Plastic syringes were selected because they had better flow characteristics than ground glass syringes. Glass tubes were chosen because of better transparency leading to better photographs.

Photographic testing became the major problem with the Liesegang Band experiment. The original placement of the flash attachment blocked the view of the Surface Tension experiment which is to be mounted above the Liesegang Band tubes. Both experiments will be photographed by the same camera. The light intensity of the next flash attachment bleached out all pictures. At the present time, it is felt that a ring flash, with the bottom and sides covered with tape so the light can be bounced off of the top of the experiment, will be an acceptable light source. Testing continues.

POST FLIGHT

For most experiments, most of the work is completed when the can is sealed for launch. But for some, the work does not begin until after the experiment is returned.

Once the Cosmic Ray project has been returned to the school, the process of data reduction - collecting, interpreting, comparing, and concluding - begins. The Cosmic Ray project utilized a special plastic - allyl diglycol polycarbonate or CR-39 - to collect a record of high energy ionized particles which pass through the plastic at a range of 8 to 30 MeV/amu (those of higher energy cannot be detected by CR-39). The CR-39 will be arranged into two blocks of fifty sheets - each sheet being 20 microns thick - per block. The two blocks will be placed in areas of minimum shielding to maximize exposure to cosmic rays. The blocks are made of .25 inch Lexan, thinned to .125 inches in the center to reduce absorption of cosmic rays through the block. The cosmic rays which pass through the plastic leave a weak spot or track in each sheet through which they pass. Thus a permanent record of the cosmic rays is made.

To uncover this record the CR-39 sheets, numbered for identification, are exposed to 6.25M NaOH at 70 degrees C. The sheets are removed from the hot NaOH before the CR-39 is totally dissolved, thus more plastic is dissolved in the weak spots or tracks where the cosmic rays have passed. With the help of high power microscopes and computers, the width, depth, angle, and shape of a cosmic ray track can be measured. These computers will also help in analyzing the four measurements by comparing the data with reliable data from other similar experiments. This will help to determine the origin, type, and velocity of each recorded cosmic ray. These results are used to study the composition of the sun and possibly solar flares as well as stellar bodies, new cosmic rays, and the space environment. Finally, the data will be compared to other cosmic ray experiments to determine the validity of the work and to draw conclusions.

CONCLUSION

This paper has presented the process by which each of the fourteen projects advanced from abstract ideas into a workable microgravity experiment. All of the experiments in the G-376 program were conceived, designed, built, and tested either by students directly or with students involved.

TABLE ONE: EXPERIMENT SUMMARY

EXPERIMENT	SCHOOL	TYPE	DATA METHOD
Gene Jumping	Friendly	Microbiological	Returned samples
Radish Seeds	Bowie	Biological	Photographs
Liesegang Bands	Oxon Hill	Science	Photographs
Surface Tension	Oxon Hill	Science	Photographs
Cosmic Ray	Roosevelt	Science	Returned samples
Nematode	Roosevelt	Biological	Returned samples
Bacteriophage	Suitland	Microbiological	Returned samples
Protein Production	B-CC	Microbiological	Returned samples
Planaria	Blair	Biological	Returned samples
Capillary Action	Blair	Science	Memory chip
Immiscible Liquids	Gaithersburg	Science	Memory chip
Polyethylene Melt	Seneca Valley	Material Processing	Returned samples
Solid Foam	Thomas Wooton	Material Processing	Returned samples
Brine Shrimp	Thomas Wooton	Biological	Returned samples

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